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(REV 5-93)

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER
381NP/50398TRANSMITTAL LETTER TO THE UNITED STATES
DESIGNATED/ELECTED OFFICE (DO/EO/US)
CONCERNING A FILING UNDER 35 U.S.C. 371U.S. APPLICATION NO. (if known, see
37 CFR 1.5)09/936481
PRIORITY DATE CLAIMED

INTERNATIONAL APPLICATION NO.

INTERNATIONAL FILING DATE

PCT/JP99/05115

20 September 1999

TITLE OF INVENTION

MOTOR GENERATOR IN HYBRID CAR AND CONTROL METHOD THEREOF

APPLICANT(S) FOR DO/EO/US

Masao TAHARA, Hong Joong KIM, Tsunehiro ENDO, Ryoso MASAKI, Kou AJIMA, Toshiyuki INNAMI, Keichi MASHINO,
Takeshimi SAKURAI

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay
Examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☐ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2)).
 - a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☒ has been transmitted by the International Bureau.
 - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
 - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☐ have been transmitted by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)) (unexecuted)
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36
(35 U.S.C. 371(c)(5)).

Item 11. to 16. below concern other document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment.
- ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☐ A substitute specification and marked-up copy thereof.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information:
 - a. Form PCT/IB/308;
 - b. 9 sheets of drawings showing Figs. 1-11, 12a, 12b
 - c. Japanese Search Report



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U.S. APPLICATION NO. (Information, see 37 CFR 1.5) 09/736481		INTERNATIONAL APPLICATION NO. PCT/JP99/05115		ATTORNEY'S DOCKET NUMBER 381NP/50398	
17. <input checked="" type="checkbox"/> The following fees are submitted:				CALCULATIONS	PTO USE ONLY
Basic National Fee (37 CFR 1.492(a)(1)-(5)):					
Search Report has been prepared by the EPO or JPO				\$ 860.00	
International preliminary examination fee paid to USPTO (37 CFR 1.482)				\$ 690.00	
No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2))				\$ 710.00	
Neither international preliminary examination fee (37 CFR 1.482) nor International search fee (37 CFR 1.445(a)(2)) paid to USPTO				\$ 1000.00	
International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4)				\$ 100.00	
ENTER APPROPRIATE BASIC FEE AMOUNT =				\$ 860.00	
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input checked="" type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				\$130.00	
Claims	Number Filed	Number Extra	Rate		
Total Claims	26 - 20 =	6	X \$18.00	\$108.00	
Independent Claims	4 - 3 =	1	X \$80.00	\$80.00	
Multiple dependent claims(s) (if applicable)			+ \$270.00	\$	
TOTAL OF ABOVE CALCULATIONS =				\$1178.00	
Applicant claims Small Entity Status (See 37 CFR §1.27) <input type="checkbox"/> yes <input type="checkbox"/> no. Reduction by 1/2 for filing by small entity, if applicable.				\$	
SUBTOTAL =				\$1178.00	
Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				\$	
TOTAL NATIONAL FEE =				\$1178.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28,3.31). \$40.00 per property +				\$	
TOTAL FEE ENCLOSED =				\$1178.00	
				Amount to be: refunded	\$
				Charged	\$
a. <input type="checkbox"/> Two checks in the amount of \$_____ the filing fee and \$_____ for the assignment recording fee are enclosed					
b. <input checked="" type="checkbox"/> Please charge my Deposit Account No. 05-1323 (Docket #381NP/50398) in the amount of \$1178.00 to cover the above fees. A duplicate copy of this sheet is enclosed.					
c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees, which may be required, or credit any overpayment to Deposit Account No. 05-1323. A duplicate copy of this sheet is enclosed.					
NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.					
SEND ALL CORRESPONDENCE TO:					
Crowell & Moring, L.L.P.			SIGNATURE		
P.O. Box 14300			Jeffrey D. Sanok		
Washington, D.C. 20044-4300			NAME		
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Fax No. (202) 628-8844			REGISTRATION NUMBER		
			September 14, 2001		
			DATE		

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Attorney Docket: 381NP/50398
PATENTIN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: KAZUO TAHARA ET AL.

Serial No.: NOT YET ASSIGNED PCT NO.: PCT/JP99/05115

Filed: SEPTEMBER 14, 2001

Title: MOTOR GENERATOR IN HYBRID CAR AND CONTROL METHOD
THEREOFPRELIMINARY AMENDMENT

Box PCT

Commissioner for Patents
Washington, D.C. 20231

Sir:

Please enter the following amendments to the claims prior
to the examination of the application.

IN THE CLAIMS:

Please cancel claims 1-14 presently in the application
and substitute new claims 15-40 as follows:

15. (new) A power generator in a hybrid car comprising:
a motor generator mechanically connected with the crank
shaft of an internal combustion engine for driving a car
wherein said internal combustion engine is started by electric
power supplied by a battery and power is generated by rotation
from said internal combustion engine to charge a battery, an
inverter for controlling the drive and power generation of a

motor generator, and a control circuit for controlling said inverter;

said hybrid car further characterized in that;

said motor generator is driven by battery power to start said internal combustion engine, and, after said internal combustion engine has started, said battery is charged by the generator mode operation of said motor generator using the power of said internal combustion engine;

wherein a step-down chopper circuit is provided between the battery and the inverter, and step-down control is provided to ensure that the power generation voltage will reach the level of the battery charging voltage through a step-down chopper circuit.

16. (new) A power generator in a hybrid car comprising:

a motor generator mechanically connected with the crank shaft of an internal combustion engine for driving a car wherein said internal combustion engine is started by electric power supplied by a battery and power is generated by rotation from said internal combustion engine to charge a battery, an inverter for controlling the drive and power generation of a motor generator, and a control circuit for controlling said inverter;

said hybrid car further characterized in that;

said motor generator is driven by battery power to start said internal combustion engine, and, after said internal

combustion engine has started, said battery is charged by the generator mode operation of said motor generator using the power of said internal combustion engine;

wherein a step-up chopper circuit is provided on the output side of the battery, and, when the motor generator is started by the electric power of the battery, the battery voltage is stepped up to drive said motor generator and to start said internal combustion engine.

17. (new) A power generator in a hybrid car according to Claim 15 characterized in that said motor generator is a permanent magnet field motor generator having its rotor equipped with a permanent magnet and constituting a field pole or a jaw type magnetic pole synchronous motor generator having its rotor with jaw type magnetic pole field, wherein the weak field rate is 1 to less than 4.

18. (new) A power generator in a hybrid car according to Claim 16 characterized in that said motor generator is a permanent magnet field motor generator having its rotor equipped with a permanent magnet and constituting a field pole or a jaw type magnetic pole synchronous motor generator having its rotor with jaw type magnetic pole field, wherein the weak field rate is 1 to less than 4.

19. (new) A power generator in a hybrid car according to Claim 15 characterized in that said motor generator is an induction motor generator having its rotor equipped with multiple secondary conductors and the weak field rate is 1 to 3 or more.

20. (new) A power generator in a hybrid car according to Claim 16 characterized in that said motor generator is an induction motor generator having its rotor equipped with multiple secondary conductors and the weak field rate is 1 to 3 or more.

21. (new) A power generator in a hybrid car according to Claim 15 characterized in that said battery comprises an auxiliary battery of 14-volt charging voltage as a light source for a lamp or the like, and a main battery of 42-volt charging voltage;

said internal combustion engine is started by the electric power supplied from said main battery through said motor generator;

power is generated by said motor generator through rotation from said internal combustion engine, thereby charging the main battery; and

the battery is charged by operation of said motor generator in the generation mode using the power of the

internal combustion engine after said internal combustion engine has started;

wherein, if the voltage generated by said motor generator is greater than charging voltage of said main battery, voltage control is performed by said step-down chopper circuit to step down said voltage until it agrees with the charging voltage of said main battery.

22. (new) A power generator in a hybrid car according to Claim 16 characterized in that said battery comprises an auxiliary battery of 14-volt charging voltage as a light source for a lamp or the like, and a main battery of 42-volt charging voltage;

said internal combustion engine is started by the electric power supplied from said main battery through said motor generator;

power is generated by said motor generator through rotation from said internal combustion engine, thereby charging the main battery; and

the battery is charged by operation of said motor generator in the generation mode using the power of the internal combustion engine after said internal combustion engine has started;

wherein, if the voltage generated by said motor generator is greater than charging voltage of said main battery, voltage control is performed by said step-down chopper circuit to step

down said voltage until it agrees with the charging voltage of said main battery.

23. (new) A power generator in a hybrid car according to Claim 17 characterized in that said battery comprises an auxiliary battery of 14-volt charging voltage as a light source for a lamp or the like, and a main battery of 42-volt charging voltage;

said internal combustion engine is started by the electric power supplied from said main battery through said motor generator;

power is generated by said motor generator through rotation from said internal combustion engine, thereby charging the main battery; and

the battery is charged by operation of said motor generator in the generation mode using the power of the internal combustion engine after said internal combustion engine has started;

wherein, if the voltage generated by said motor generator is greater than charging voltage of said main battery, voltage control is performed by said step-down chopper circuit to step down said voltage until it agrees with the charging voltage of said main battery.

24. (new) A power generator in a hybrid car according to Claim 19 characterized in that said battery comprises an

auxiliary battery of 14-volt charging voltage as a light source for a lamp or the like, and a main battery of 42-volt charging voltage;

said internal combustion engine is started by the electric power supplied from said main battery through said motor generator;

power is generated by said motor generator through rotation from said internal combustion engine, thereby charging the main battery; and

the battery is charged by operation of said motor generator in the generation mode using the power of the internal combustion engine after said internal combustion engine has started;

wherein, if the voltage generated by said motor generator is greater than charging voltage of said main battery, voltage control is performed by said step-down chopper circuit to step down said voltage until it agrees with the charging voltage of said main battery.

25. (new) A motor generator control method for a hybrid car comprising:

a motor generator mechanically connected with the crank shaft of an internal combustion engine for driving a car wherein said internal combustion engine is started by electric power supplied by a battery and power is generated by rotation from said internal combustion engine to charge a battery, an

inverter for controlling the drive and power generation of a motor generator, and a control circuit for controlling said inverter;

said hybrid car further characterized in that;

if the voltage generated by said motor generator is greater than charging voltage of said main battery, voltage step-down control is performed by a step-down chopper circuit to step down said voltage until it agrees with the charging voltage of said main battery.

26. (new) A motor generator control method for a hybrid car according to Claim 25 characterized in that said battery is charged by operation of said motor generator in the generation mode wherein;

if the voltage generated by said motor generator is greater than charging voltage of said main battery, said voltage is stepped down by said step-down chopper circuit;

at the same time, and the current phase of the stator winding of said motor generator is controlled to get weak field component by armature reaction magnetic flux to ensure that said generated voltage agrees with said battery charging voltage.

27. (new) A motor generator control method for a hybrid car comprising:

a motor generator mechanically connected with the crank shaft of an internal combustion engine for driving a car wherein said internal combustion engine is started by electric power supplied by a battery and power is generated by rotation from said internal combustion engine to charge a battery, an inverter for controlling the drive and power generation of a motor generator, and a control circuit for controlling said inverter;

said hybrid car further characterized in that;

when said motor generator is started by electric power of said battery, a step-up chopper circuit is provided on the output side of said battery to step up said battery voltage to drive said motor generator and start said internal combustion engine, and;

if the voltage generated by said motor generator is greater than charging voltage of said main battery, voltage step-down control is performed by a step-down chopper circuit to step down said voltage until it agrees with the charging voltage of said main battery.

28. (new) A motor generator control method for a hybrid car according to Claim 27 characterized in that, in the startup operation by said motor generator, the current phase of a stator winding is controlled by an inverter to get strong field current component whereby said internal combustion engine is started.

29. (new) A motor generator control method for a hybrid car according to Claim 27 characterized in that;

said motor generator is a permanent magnet synchronous motor generator or jaw type magnetic pole synchronous motor generator;

when said internal combustion engine is started, strong field control is made by the inverter until the rotational speed requiring the maximum torque is reached, and, at the same time, the step-up chopper circuit is operated to make motor-applied voltage greater than the battery voltage and to get the motor current to have a specified current value, thereby obtaining the maximum torque; and

when torque assist function is used until a high rotational speed is reached, weak field current component control is performed through control of the current phase of said stator winding, and, at the same time, the step-up chopper circuit is operated to increase the motor applied voltage so that the motor current is kept at the minimum.

30. (new) A motor generator control method for a hybrid car according to Claim 25 characterized in that;

said motor generator is a permanent magnet synchronous motor generator or jaw type magnetic pole synchronous motor generator;

when power is generated by said motor generator after start of said internal combustion engine is started, stator winding current phase is controlled to get strong field current component if the internal combustion engine speed is close to idling speed;

then with the increase in internal combustion engine speed, the current phase of said stator winding is controlled to get strong field current component, thereby keeping generation voltage at the level of charging voltage; and

with further increase in engine speed, generation voltage is stepped down by the step-down chopper circuit with the state of weak field current component kept unchanged, and voltage control is made to ensure that generation voltage agrees with battery charging voltage.

31. (new) A motor generator control method for a hybrid car according to Claim 27 characterized in that;

said motor generator is an induction motor generator;

when said internal combustion engine is started, the current phase of said stator winding is controlled so that strong field control component is obtained until the rotational speed requiring the maximum torque is reached, and at the same time, the step-up chopper circuit is operated to make motor-applied voltage greater than the battery voltage, thereby obtaining the maximum torque even if the stator

winding current is small at the time of internal combustion engine startup; and

when torque assist function is used until a high rotational speed is reached, weak field control is performed, and, at the same time, the step-up chopper circuit is operated to increase the motor-applied voltage, thereby obtaining the assist torque.

32. (new) A motor generator control method for a hybrid car according to Claim 27 characterized in that;

when said motor generator is started by said battery power, a step-up chopper circuit is installed on the output side of said battery and the conversion voltage ratio of said battery voltage is set at 1.5 times or more, to ensure that the current capacity of the switching element of said inverter main circuit is smaller than that of the switching element of said step-up chopper circuit.

33. (new) A motor generator control method for a hybrid car according to Claim 25 characterized in that said battery comprises a auxiliary battery of 14-volt charging voltage as a light source for a lamp or the like, and a main battery of 42-volt charging voltage;

said internal combustion engine is started by the electric power supplied from said main battery through said motor generator;

power is generated by said motor generator through rotation from said internal combustion engine, thereby charging the main battery; and

the battery is charged by operation of said motor generator in the generation mode using the power of the internal combustion engine after said internal combustion engine has started;

wherein, if the generation voltage of said motor generator is greater than the charging voltage of said main battery, voltage control is performed to step down the generation voltage through said step-down chopper circuit so that it agrees with the charging voltage of said main battery is reached.

34. (new) A motor generator control method for a hybrid car according to Claim 26 characterized in that said battery comprises a auxiliary battery of 14-volt charging voltage as a light source for a lamp or the like, and a main battery of 42-volt charging voltage;

said internal combustion engine is started by the electric power supplied from said main battery through said motor generator;

power is generated by said motor generator through rotation from said internal combustion engine, thereby charging the main battery; and

the battery is charged by operation of said motor generator in the generation mode using the power of the internal combustion engine after said internal combustion engine has started;

wherein, if the generation voltage of said motor generator is greater than the charging voltage of said main battery, voltage control is performed to step down the generation voltage through said step-down chopper circuit so that it agrees with the charging voltage of said main battery is reached.

35. (new) A motor generator control method for a hybrid car according to Claim 27 characterized in that said battery comprises a auxiliary battery of 14-volt charging voltage as a light source for a lamp or the like, and a main battery of 42-volt charging voltage;

said internal combustion engine is started by the electric power supplied from said main battery through said motor generator;

power is generated by said motor generator through rotation from said internal combustion engine, thereby charging the main battery; and

the battery is charged by operation of said motor generator in the generation mode using the power of the internal combustion engine after said internal combustion engine has started;

wherein, if the generation voltage of said motor generator is greater than the charging voltage of said main battery, voltage control is performed to step down the generation voltage through said step-down chopper circuit so that it agrees with the charging voltage of said main battery is reached.

36. (new) A motor generator control method for a hybrid car according to Claim 28 characterized in that said battery comprises a auxiliary battery of 14-volt charging voltage as a light source for a lamp or the like, and a main battery of 42-volt charging voltage;

said internal combustion engine is started by the electric power supplied from said main battery through said motor generator;

power is generated by said motor generator through rotation from said internal combustion engine, thereby charging the main battery; and

the battery is charged by operation of said motor generator in the generation mode using the power of the internal combustion engine after said internal combustion engine has started;

wherein, if the generation voltage of said motor generator is greater than the charging voltage of said main battery, voltage control is performed to step down the generation voltage through said step-down chopper circuit so that it

agrees with the charging voltage of said main battery is reached.

37. (new) A motor generator control method for a hybrid car according to Claim 29 characterized in that said battery comprises a auxiliary battery of 14-volt charging voltage as a light source for a lamp or the like, and a main battery of 42-volt charging voltage;

said internal combustion engine is started by the electric power supplied from said main battery through said motor generator;

power is generated by said motor generator through rotation from said internal combustion engine, thereby charging the main battery; and

the battery is charged by operation of said motor generator in the generation mode using the power of the internal combustion engine after said internal combustion engine has started;

wherein, if the generation voltage of said motor generator is greater than the charging voltage of said main battery, voltage control is performed to step down the generation voltage through said step-down chopper circuit so that it agrees with the charging voltage of said main battery is reached.

38. (new) A motor generator control method for a hybrid car according to Claim 30 characterized in that said battery comprises a auxiliary battery of 14-volt charging voltage as a light source for a lamp or the like, and a main battery of 42-volt charging voltage;

said internal combustion engine is started by the electric power supplied from said main battery through said motor generator;

power is generated by said motor generator through rotation from said internal combustion engine, thereby charging the main battery; and

the battery is charged by operation of said motor generator in the generation mode using the power of the internal combustion engine after said internal combustion engine has started;

wherein, if the generation voltage of said motor generator is greater than the charging voltage of said main battery, voltage control is performed to step down the generation voltage through said step-down chopper circuit so that it agrees with the charging voltage of said main battery is reached.

39. (new) A motor generator control method for a hybrid car according to Claim 31 characterized in that said battery comprises a auxiliary battery of 14-volt charging voltage as a

light source for a lamp or the like, and a main battery of 42-volt charging voltage;

said internal combustion engine is started by the electric power supplied from said main battery through said motor generator;

power is generated by said motor generator through rotation from said internal combustion engine, thereby charging the main battery; and

the battery is charged by operation of said motor generator in the generation mode using the power of the internal combustion engine after said internal combustion engine has started;

wherein, if the generation voltage of said motor generator is greater than the charging voltage of said main battery, voltage control is performed to step down the generation voltage through said step-down chopper circuit so that it agrees with the charging voltage of said main battery is reached.

40. (new) A motor generator control method for a hybrid car according to Claim 32 characterized in that said battery comprises a auxiliary battery of 14-volt charging voltage as a light source for a lamp or the like, and a main battery of 42-volt charging voltage;

said internal combustion engine is started by the electric power supplied from said main battery through said motor generator;

power is generated by said motor generator through rotation from said internal combustion engine, thereby charging the main battery; and

the battery is charged by operation of said motor generator in the generation mode using the power of the internal combustion engine after said internal combustion engine has started;

wherein, if the generation voltage of said motor generator is greater than the charging voltage of said main battery, voltage control is performed to step down the generation voltage through said step-down chopper circuit so that it agrees with the charging voltage of said main battery is reached.

REMARKS

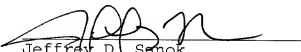
Entry of the amendments to the claims before examination of the application is respectfully requested.

If there are any questions regarding this amendment or the application in general, a telephone call to the undersigned would be appreciated since this should expedite the prosecution of the application for all concerned.

If necessary to effect a timely response, this paper should be considered as a petition for an Extension of Time sufficient to effect a timely response, and please charge any deficiency in fees or credit any overpayments to Deposit Account No. 05-1323 (Docket #381NP/50398).

Respectfully submitted,

September 14, 2001



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SPECIFICATION

MOTOR GENERATOR IN HYBRID CAR AND CONTROL METHOD
THEREOF

5 TECHNICAL FIELD

The invention relates to a motor generator and its control method in a hybrid car comprising a motor generator connected to an engine as a drive source, and particularly to a motor generator and its control method capable of
10 controlling the armature current phase and adjusting field current component.

BACKGROUND ART

There are two methods for driving a hybrid car
15 according to the prior art: One is a series hybrid method wherein power is obtained by driving a generator by the driving speed of an engine as an internal combustion engine, and this power is used to drive the motor connected to the axle, then a car is driven by the driving force of the motor
20 (Japanese Application Patent Laid-Open Publication No. Hei 08-298696, Japanese Application Patent Laid-Open Publication No. Hei 06-245322 and Official Gazette of USP 5214358, for example). The other is a parallel hybrid method wherein part of the driving force of the internal
25 combustion engine is converted into electric power, and

the remaining driving force is transmitted to the axle as driving force. Thus, the car is driven by both of motor driving force provided by generated electric power and axle driving force given by an internal combustion engine
5 (Official Gazette of USP 5081365, for example).

According to the prior art, however, two motors and inverter circuits for driving these motors are necessary, and a new planetary gear mechanism must be installed. This requires a substantial improvement of a car, and resulting
10 increase in costs cannot be avoided.

To solve this problem, a one-motor method is proposed as disclosed in the Official Gazette of Japanese Application Patent Laid-Open Publication No. Hei 07-298696. According to this method, an electric rotating
15 machine is directly coupled to the crank shaft of an internal combustion engine, and driving and power generation are performed by one electric rotating machine through switching of operation mode. This method is more advantageous than the two-motor method discussed above in
20 that the cost is lower and this feature can be added onto the current car.

For both the one-motor method and two-motor method, the following motor generator is used as an electric rotating machine; (1) a synchronous magnet type motor
25 generator with a permanent magnet mounted on the rotor,

(2) a synchronous motor generator of jaw type magnetic pole based on the same principle as that of an alternator as a car generator, or (3) a squirrel cage type induction motor generator with a secondary conductor of squirrel cage type installed on the rotor. Inverter control is adopted as follows: When the internal combustion engine is started, the output voltage of a 42-volt battery is adjusted by controlling the voltage, current and frequency by an inverter, and the motor generator is driven in the motor operation mode. After the internal combustion engine has started, the motor generator is driven in power generation mode so that power generation voltage will reach the level of battery charging voltage.

In the meantime, Japanese Application Patent Laid-Open Publication No. Hei 11-220812 discloses the method wherein a step up/down chopper is installed between the battery and inverter to ensure that d. c. input voltage of the inverter or the like is kept almost constant.

[PROBLEMS TO BE SOLVED BY THE INVENTION]

The following problems are found in the one-motor type motor generator used as a motor generator in a hybrid car:

(1) Compatibility must be ensured between high torque characteristic in the low speed area at the start of the internal combustion engine, and high output power generation characteristic capable of getting a high power

generation current in the range from idling speed to high speed.

5 (2) There is a relation of 1 to 10 or more between the rotational speed (about 700 rpm) for generating torque (maximum torque generated by the motor) required at the start of internal combustion engine in (1) and motor rotational speed (6000 rpm or more) at the maximum permissible rotational speed of the internal combustion engine.

10 (3) There is a shortage of the assist torque for promoting the torque of internal combustion engine at the rotational speed equal to or greater than the rotational speed when the internal combustion engine starts.

15 (4) The motor generator mounted on the car operates in the motor operation mode at the time of startup and generates power in the generator mode. A battery which is charged or discharged within the voltage fluctuation range with reference to a certain voltage is used as a power source. So the battery may be damaged in the worst case if it is
20 charged with the voltage far exceeding the battery charging voltage, for example, at a high speed of the internal combustion engine.

The above problems must be solved when any one of the above-mentioned motor generators is used. Generally,
25 when the motor of the motor generator is operated,

rotational speed N is proportional to the applied voltage V and is inversely proportional to field magnetic flux ϕ .

Torque τ is proportional to the product of motor current I_m and field magnetic flux ϕ . The counter electromotive force in motor operation and power generation voltage in generator mode operation are proportional to the product of rotational speed N and field magnetic field ϕ .

Accordingly, the system must be configured to ensure that any motor generator can provide the required torque and generation power even when the rotational speed range is wide.

Generally, current phase is controlled in such a way that strong field current component is obtained when a high torque is required at a low rotational speed, and weak field current component is obtained at a high rotational speed to reduce counter electromotive force.

However, when the motor generator is operated in the generation mode, generation is performed in the range from the idling speed (about 700 rpm) of the internal combustion engine to the maximum rotational speed (6000 rpm or more) of the internal combustion engine. So at a high rotational speed, power generation voltage becomes excessive in the method of adjusting the current phase of the stator winding. As a result, there is a shortage of weak field current component, and it is difficult to reach agreement with

battery charging voltage. Further, when the internal
combustion engine is started by motor operation, the
starting current of the motor is excessive, current
capacity of the switching element in the main circuit of
5 the inverter becomes excessive, and this gives rise to
problems.

The object of the present invention is to solve the
above-mentioned problems and to provide a motor generator
and control method thereof in a battery-mounted hybrid car
10 wherein the motor generator connected to an internal
combustion engine is operated in the motor operation mode
or generator operation mode within the range from high to
low speeds. This motor generator and control method
thereof is further characterized in that stable power
15 torque characteristic and power generation characteristic
can be obtained and highly efficient control is ensured.

DISCLOSURE OF INVENTION

The present invention is characterized by a hybrid car
20 comprising a motor generator mechanically connected with
the crank shaft of an internal combustion engine for
driving a car wherein the internal combustion engine is
started by electric power supplied by a battery and power
is generated by rotation from the internal combustion
25 engine to charge the battery, an inverter for controlling

the drive and power generation of the motor generator, and a control circuit for controlling the inverter, this hybrid car further characterized in that the motor generator is driven by battery power to start the internal combustion engine, and after the internal combustion engine has started, the battery is charged by the generator mode operation of the motor generator using the power of the internal combustion engine, wherein a step-down chopper circuit is provided between the battery and the inverter, and step-down control is provided to ensure that the power generation voltage will reach the level of the battery charging voltage through the step-down chopper circuit.

The present invention is further characterized by a hybrid car comprising a motor generator mechanically connected with the crank shaft of an internal combustion engine for driving a car wherein the internal combustion engine is started by electric power supplied by a battery and power is generated by rotation from the internal combustion engine to charge the battery, an inverter for controlling the drive and power generation of the motor generator, and a control circuit for controlling the inverter, this hybrid car still further characterized in that the motor generator is driven by battery power to start the internal combustion engine, and, after the internal combustion engine has started, the battery is charged by

the generator mode operation of the motor generator using the power of the internal combustion engine, wherein a step-up chopper circuit is provided on the output side of the battery, and, when the motor generator is started by the electric power of the battery, the battery voltage is stepped up to drive the motor generator and to start the internal combustion engine.

The present invention is further characterized by a motor generator control method for a hybrid car comprising a motor generator mechanically connected with the crank shaft of an internal combustion engine for driving a car wherein the internal combustion engine is started by electric power supplied by a battery and power is generated by rotation from the internal combustion engine to charge the battery, an inverter for controlling the drive and power generation of the motor generator, and a control circuit for controlling the inverter, this hybrid car still further characterized in that the motor generator is driven by battery power to start the internal combustion engine, and, after the internal combustion engine has started, the battery is charged by the generator mode operation of the motor generator using the power of the internal combustion engine, wherein step-down control is provided to ensure that the power generation voltage will reach the level of the battery charging voltage through the step-down chopper

circuit when the power generation voltage of the motor generator is higher than the battery charging voltage.

According to the present invention, when the motor generator is used as a motor to start the internal
5 combustion engine or to provide torque assist, battery voltage is stepped up by the step-up circuit and is applied to the inverter input. At the same time, the inverter provides control to get the rotational speed specified by a command. In other words, the current phase of the stator
10 winding is adjusted and the amount of field magnetic flux component is regulated, thereby obtaining a specified speed, a specified armature current and a specified torque. This allows a high voltage to be obtained by means of a step-up chopper circuit and permits the field current
15 component, hence, starting torque to be increased.

Further, when power generation voltage is greater than battery charging voltage in the generation operation mode, a high power generation voltage can be stepped down by a
step-down chopper provided between the battery and
20 inverter input terminal to reach agreement with battery charging voltage.

As described above, the present invention provides a motor generator and control method thereof in a battery-mounted hybrid car wherein the motor generator
25 connected to the internal combustion engine is operated

in the motor or generator mode within the range from low to high speed. Stable power torque characteristic and power generation characteristic can be obtained and highly efficient control is ensured.

5

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram representing the system configuration of a motor generator for a car as one embodiment of the present invention;

10 Fig. 2 is a circuit configuration diagram representing a motor generator and system as one embodiment of the present invention;

Fig. 3 is an explanatory diagram representing the operation mode of the present invention;

15 Fig. 4 is a flow diagram representing the operation of the present invention;

Fig. 5 is an explanatory diagram representing the system operation when the step-down chopper is operating in the generator mode of the motor generator as one
20 embodiment of the present invention;

Fig. 6 is an explanatory diagram representing the step-down chopper;

Fig. 7 is a block diagram representing the system configuration of a motor generator for a car as another
25 embodiment of the present invention;

Fig. 8 is a circuit configuration diagram representing a motor generator and system as the embodiment of Fig. 7;

Fig. 9 is a flow diagram representing the operation in another embodiment of the present invention;

5 Fig. 10 is an explanatory diagram representing the step-up chopper;

Fig. 11 is an explanatory diagram representing the system operation in the motor operation mode of the motor generator with respect to the rotational speed when the step-up chopper circuit is operating as another embodiment of the present invention, and also representing the torque characteristic and weak field current; and

10

Fig. 12 is an explanatory diagram representing the changes in the starting torque in the motor operation mode of the motor generator with different rotational speed range and the field current component obtained by phase adjustment of stator winding current with respect to rotational speed.

15

20 BEST EMBODIMENTS FOR CARRYING OUT THE INVENTION

The following describes embodiments according to the present invention with reference to drawings: Fig. 1 is a block diagram representing the basic configuration of the motor generator system in a hybrid car adopting a permanent magnet field type synchronous motor generator.

25

In the motor generator system of Fig. 1, a motor generator 3 drives an internal combustion engine 1 and operates in the generator mode after the internal combustion engine 1 has started. The main battery 10 for high voltage (for example, 42-volt system) is charged with generated power. In this configuration, a motor generator 3 of flat structure is installed between the internal combustion engine 1 and transmission 2. The motor generator 3 is a permanent magnet field type synchronous motor generator in this case. The output of the motor generator 3 is led to the step-down chopper circuit 9 through the inverter main circuit 5, and the generated voltage is stepped down to reach the level of the specified battery charging voltage at the step-down chopper circuit 9 and is supplied to the main battery 10. Further, auxiliary battery 8 for low voltage (14 volts, for example) is connected to the step-down chopper circuit 9 in parallel with the main battery 10. The auxiliary battery 8 is connected to a lamp load and audio equipment (not illustrated).

Overall control of a hybrid car is made by a main controller 4. The motor generator control circuit 6 controls the inverter main circuit 5 and step-down chopper circuit 9 based on the operation command signal 70 or the like from this main controller 4. According to command and

the like from the main controller 4, engine control unit 40 controls the internal combustion engine 1. Similarly, in conformity to the command or the like from the main controller 4, the battery controller 41 controls the DC-DC converter 7 to keep the output from the motor generator 3 at 14-volt charging voltage, thereby charging the voltage battery 8.

When the internal combustion engine 1 is to be started, it is started by motor mode operation of the motor generator 3. Namely, for current from the main battery 10, battery power enters the inverter main circuit 5 through the diode, and the output of the inverter main circuit 5 is controlled to become a specified electric power by the control software of the motor generator control circuit 6. The motor generator 3 operates as a motor to start the internal combustion engine 1.

In the meantime, operation of the motor generator 3 in the generation mode is to charge the battery after the internal combustion engine 1 has started. This operation holds good when the motor generator 3 is put into the generator operation mode by power from the internal combustion engine 1, and the voltage on the input side of the inverter 5 or the generation voltage V_g on the side of motor generator 3 and battery charging voltage $Bb1$ has a relation of is $V_{b1} \leq V_g$. Regardless of any mode of car

operation, V_g is controlled to reach the level of battery charging voltage when the battery is charged. If generation voltage V_g is greater than battery charging voltage V_{b1} , it is controlled by the motor generator control circuit 6 constituting the main circuit 5 of the inverter. The mount of field magnetic flux component is controlled to reach weak field by the current phase control of armature current to ensure that generation voltage will reach the level of battery charging voltage.

Fig. 2 shows an example of a detailed circuit. A motor generator 3 is installed between the internal combustion engine 1 and transmission 2. A step-down chopper circuits 9 are installed among the inverter 5, main battery 10 and auxiliary battery 8. The motor generator control circuit 6 contains a microcomputer for control 61 and driver signal circuit 62. The microcomputer 61 for control contains a central processor unit, memory and various control software programs stored in the memory. It incorporates the operation command signal 70 from the main controller 4, inverter input voltage signal 63, charging voltage signal 64, the current of motor generator 3 and position detecting signal (and rotational speed signal) 65, and generates and outputs the control signal of the driver signal circuit 62 and the control signal of the step-down chopper circuit 9.

The rotor of the permanent magnet field type synchronous motor generator 3 is composed of a rotor core 31 and permanent magnet field 32 constituting the magnetic pole. A jaw type magnetic pole motor generator can be used as the motor generator. In that case, the rotor is made up of jaw type magnetic south and north poles surrounding the exciting coil. Further, an induction motor may be used as the motor generator. In that case, the rotor is formed with secondary conductors arranged in a squirrel cage shape in the slot inside the rotor core.

In the meantime, the stator is designed in a structure with three-phase stator winding 34 wound in the slot provided inside the stator core 33. A housing 35 is shrinkage-fit on the periphery. A water cooling passage (not illustrated) for cooling is provided. Either of the normal distributed winding and concentrated winding can be used for three-phase stator winding 34.

The rotors (31 and 32) of the motor generator 3 are directly connected with the crank shaft of the internal combustion engine 1. If the motor generator 3 is installed inside the transmission 2, the rotor of the motor generator 3 is directly connected to the shaft of the transmission.

The terminal of the three-phase stator winding on the permanent magnet type inductive synchronous motor generator 3 mechanically connected to the internal

combustion engine 1 is electrically connected to the inverter main circuit 5 through three-phase wiring 4. The inverter main circuit 5 comprises the switching elements 51a to 51f of each three-phase arm and feedback diodes 52a to 52f. The switching operation of switching element 51a to 51f is performed by the driver signal generator 62 of the M/G control circuit 6. Driver signal circuit 62 is controlled by the control signal of the microcomputer 61 for control.

A smoothing capacitor 11 is mounted on the input side of the inverter main circuit 5. Further, a step-down choppers 9 are installed among the main battery 10, capacitor 12 and smoothing capacitor 11. The step-down chopper 9 is composed of a switching element 91, antiparallel circuit of diode 92, reactor 93 and diode 94.

In Fig. 2, when the internal combustion engine 1 is started, electric power of the main battery 10 charges the capacitor 12. It also charges the smoothing capacitor 11 through reactor 93 and diode 92, and the voltage is applied to the inverter main circuit 5. The motor generator control circuit 6 for operation of the inverter main circuit 5 incorporates the position signal (and rotational speed signal) 65 from the position detecting circuit 37 into a microcomputer 61 by the detecting signal of position sensor (hall IC, resolver, etc.) 36 of the motor generator

3. The output from the smoothing capacitor 11 and main battery 10 or signal 64 of charging voltage (inverter input voltage) is detected and incorporated into the control microcomputer 61. The microcomputer 61 uses in the motor operation mode operation command signal 70, position detecting signal (and rotational speed signal) 65, battery output voltage signal 64 and inverter input voltage signal 63 and other detecting signals to create signals to be sent to the driver signal generator 62, and sends driver signals to the gates of switching elements 51a to 51f to start the motor or provide torque assist.

Fig. 3 is an explanatory diagram representing the operation mode and relationship between the motor control and battery voltage V_b according to the present invention. Strong field control is carried out when the internal combustion engine is started. In other words, the control microcomputer 61 provides a 5 PWM control (pulse width modulation) of the inverter main circuit 5 in conformity to operation command signal 70 at the time of startup. To increase the starting torque, driver signal is controlled to ensure that the current phase flowing to the stator winding during motor operation is increased to I_{f1} by field current component I_f when the motor is operated (strong field control).

If torque assist function is required after internal

combustion engine has started, strong field control and step-up operation is performed. If the rotational speed has increased, driver signal is controlled to ensure that the field current component is reduced to down -If (weak
5 field control), and current phase is adjusted.

When there is a further increase in internal combustion engine speed, the generation mode is established. Generation voltage of the motor generator 3 becomes higher than the charging voltage V_{b0} of the main battery 10. So
10 while weak field control is performed or conduction rate of the step-down chopper is reduced, voltage control of the step-down chopper is performed to ensure that the generation voltage will agree with the charging voltage of the main battery 10.

15 The embodiment shown in Figs. 1 and 2, illustrates the case of the above-mentioned startup and generation operation. Other embodiments to be discussed later shows the cases of above-mentioned torque assisted operation.

The following describes the generation operation of
20 the motor generator 3 in the embodiment shown in the above-mentioned Figs. 1 and 2 with reference to Figs. 4 to 6:

Fig. 4 is a flow chart representing the generation operation of the motor generator 3. When the key switch
25 is turned on (Step 402), the internal combustion engine

is driven by the motor generator 3 (Step 404), and the internal combustion engine starts up (Step 406). If the charging voltage V_b of the main battery 10 has not reached the specified charging voltage V_b (Step 408) after it has started, the system waits until charging voltage V_b is reached (Step 410). Then check is made to see if the idling speed has reached or not (Step 412). If it is reached, generation operation mode starts. In the generation operation mode, the rotating power of the internal combustion engine 1 becomes the input of the generator input to get the generation power of voltage V_g . The generator also charges the smoothing capacitor 11 at three-phase alternating current (Steps 416 to 418) through diodes 52a to 52f of the inverter main circuit 5. If the voltage V_g of smoothing capacitor 11 has reached the charging voltage V_b of the main battery 10, the conduction rate of the switching element 91 of the step-down chopper 9 is set to 100% (Step 420) and main battery 10 is charged through reactor 93 (Step 422).

In other words, when the rotational speed of the internal combustion engine has increased, the generation voltage of the motor generator 3 reaches the level higher than the charging voltage of the main battery 5. So the current phase of the inverter main circuit 5 is controlled, and weak field control is provided to ensure that the

generation voltage is reduced. This makes it possible to control generation voltage to a certain speed. If the speed is higher, there is a limit to the winding temperature rise. So while a slight weak field control is performed or the conduction rate of the step-down chopper is reduced, the voltage control of step-down chopper is performed to ensure agreement with the charging voltage of the main battery 10.

Fig. 5 shows this operation. The horizontal axis indicates the rotational speed of the internal combustion engine 1 (rotational speed of motor generator 3). The vertical axis indicates the capacitor voltage $V_c 1$ of the smoothing capacity 11 determined by the generation voltage V_g of the motor generator 3. It shows the changes with respect to rotational speed when strong field control is made by adjustment of the phase of the armature current and when weak field control is performed.

In Fig. 5, assume that the rotational speed is N_1 in the idling mode when the internal combustion engine 1 is started. Also assume in this case that smoothing capacitor voltage resulting from generation voltage is V_{c1} with the minimum charging current maintained. In this case, if the field component of the generation motor 3 is subjected to strong field control, field current component I_{f1} is on the strong field side. When the rotational speed of the

internal combustion engine 1 rises to reach N_2 , generation voltage V_{g2} is reached, and the voltage of the smoothing capacitor reaches a large value of V_{c2} . The current phase of the motor is controlled so that the voltage V_{c2} of the
5 smoothing capacitor agrees with battery charging voltage V_{b1} , and weak field current control is performed. In this case, if control can be made by weak field current component alone to get the battery charging voltage, then the step-down chopper circuit need not operate. If the
10 rotational speed rises to N_2 or more, there will be an increase in copper loss due to weak field control. So when the rotational speed is N_2 or more, the step-down chopper circuit 9 is operated, and the voltage change ratio is set at a higher value so that the voltage V_{c2} of the smoothing
15 capacitor 11 agrees with the battery charging voltage V_{b1} , thereby charging the main battery 10.

Further, when the rotational speed of the internal combustion engine 1 rises to reach the maximum rotational speed N_1 , the weak field current component cannot be
20 increased. So voltage change ratio (V_{c3}/V_{b1}) of the step-down chopper 6 is further increased, and this permits the main battery 10 to be charged even at the maximum rotational speed. Here the amount of weak field current control and the voltage change ratio of the step-down
25 chopper can be set to ensure that the maximum generation

efficiency can be provided.

Fig. 6 shows the relationship between the rotational speed N of the internal combustion engine 1 and the voltage V_{c2} of the smoothing capacitor in the above-mentioned
5 embodiments. When rotational speed N is 700 rpm or more, there is an increase in the amount of voltage step-down due to the step-down chopper in response to the increase in the rotational speed N . Thus, the voltage V_{c2} of the smoothing capacitor is maintained at a certain value V_{b1} .

10 Let us go back to the generation operation flow of the motor generator 3 in Fig. 4. In Step 408, when the charging voltage V_b of the main battery 10 has reached the specified charging voltage V_b or charging voltage V_b has been reached by generation after startup, evaluation is made to
15 determine if the system in the idle stop mode or not (Step 424). If the idle stop mode is not established, battery voltage control continues (Step 426). In the case of idle stop for temporary operation shutdown (Step 430), the engine stops (Step 432). After the accelerator is
20 turned on again (Step 404), the engine is restarted by the motor generator 315. When the key switch is off, the engine is stopped and the system goes back to Step 4042.

Figs. 7 to 11 show an embodiment according to the present invention. As discussed earlier, when torque
25 assist function is required after start of the internal

combustion engine the strong field control and step-up operation are performed in this embodiment. The current phase is adjusted by controlling the driver signal so that the field current component is reduced down to $-I_{f2}$ (weak field control), if there is a further increase in rotational speed.

First, Fig. 7 shows the main configuration of the motor generator drive system, similarly to Fig. 1. In this embodiment, a step-up/down chopper circuit 100 having a step-down and step-up function is installed between the main battery 10 and inverter main circuit 5. In the motor operation mode, the inverter main circuit 5 and control circuit 6 are used to control the current phase of the stator winding and to operate the step-up chopper circuit 100. In the generation operation mode, the current phase of the stator winding is controlled and step-down chopper circuit 9 is operated, similarly to Fig. 1. This configuration is intended to ensure that voltage is always controlled to ensure that the generation voltage will be kept at the level of the battery charging voltage. The devices such as the main controller having the same configuration as Fig. 1 will not be illustrated.

The following mainly describes the differences from Fig. 2 using a circuit diagram of Fig. 8:

In Fig. 8, the step-up chopper circuit 100 comprises

a switching element 101 and feedback diode 102. The reactor 93 is required when the step-up chopper circuit 100 operates. Its use is shared when the step-down chopper circuit 9 operates. The low voltage battery 8 and DC-DC converter 7 are connected between the main battery 10 and step-up/down chopper circuit 100, similarly to Figs. 1 and 2.

The following describes its operation with reference to 8. To start the internal combustion engine 1, the step-up chopper circuit 100 is operated to set the voltage higher than the battery voltage when the motor generator 3 is driven as a motor, similarly to the above description.

In this case, as shown in Fig. 11, the current phase of the stator winding 34 controlled by the inverter main circuit 5 and control circuit 6 is controlled to get the field current component which provides strong field when the rotational speed of the internal combustion engine is N1. For the step-up voltage value in this case, a current limiter (not illustrated) is provided to ensure that stator winding current flows within the range of a specified acceleration current. Until the internal combustion engine 1 starts, step-up voltage is increased to raise the rotational speed to ensure that the motor current will reach a specified acceleration current.

When the internal combustion engine 1 starts to get

into the idling mode and torque assist function is used where the torque occurring to the motor is added to the torque occurring to the internal combustion engine, then the step-up chopper circuit 100 is operated to step up the voltage to be greater than battery voltage, and voltage is applied to the motor terminal. This makes it possible to provide torque assist of the internal combustion engine 1.

Fig. 10 shows the relationship between the rotational speed of the internal combustion engine 1 and motor torque τ . The step-up chopper circuit 9 is operated to get the maximum motor torque τ in the range where the speed N of the internal combustion engine 1 is 400 rpm, for example. The current phase of the motor in this case depends of the rotational speed and assist torque. The field current component in Fig. 11 is subjected to weak field control is formed so that the weak field current component can be gained with the rise of rotational speed.

Operation of the step-up chopper circuit 100 causes the main battery 101 to be short-circuited through reactor 93 at the moment when the switching element 101 installed in parallel with main battery 10 is turned on. If the switching element 101 is turned off when a big short-circuiting current flows to the reactor, the smoothing capacitor 11 is charged by energy stored in the reactor

through the diode 92. This can increase the voltage of the inverter 5 on the input side. In other words, the magnitude of voltage can be controlled, so PAM control (Pulse Amplitude Modulation) can be performed.

5 In this case, the conduction rate of the inverter main circuit 5 can be set to a greater value or 100% by means of driver signals of the control circuit 6. As a result, the input voltage of the driver signal is increased and the voltage can be increased by counter electromotive force
10 of the motor generator 3 even after the internal combustion engine 1 has started. The motor terminal voltage can be increased, so acceleration current can be fed into the stator winding of the motor. This allows generation of the torque which assists the torque of the internal combustion
15 engine 1.

If the step-up chopper circuit 100 is operated when the internal combustion engine 1 starts, current phase can be inverted-controlled, and the motor terminal voltage of the motor generator 3 can be increased in the case of the
20 same input with the result that the motor startup current can be reduced. This allows the current capacity of switching elements 51a to 51f of the inverter main circuit 5 to be reduced.

When generation operation is performed, the step-down
25 chopper circuit 9 is operated without operating the step-up

chopper circuit 100, similarly to the case shown in Fig. 2. In this case, highly efficient operation is ensured by the concurrent use of the step-down chopper circuit 9 and current phase control of the stator winding 34 by operation of the inverter main circuit 5 and control circuit 6 because of weak field.

To supply the electric power to a low voltage system in this case, voltage from the high voltage system is stepped down through DC-DC converter 10 and is controlled to get the charging voltage of the battery 8.

When the weak field current component is excessive, the copper loss of the field winding will increase. In this case, an induction motor is better than a permanent magnet type motor.

Depending on the operation mode of the car, the permanent magnet type inductive synchronous motor generator 3 is switched to the operation mode as a motor and generator. The command value for mode selection and permanent magnet type inductive synchronous power generator 3 is evaluated and computed by the main controller 4 of a car. The permanent magnet type induction synchronous motor generator 3 is controlled by entering the command value to the microcomputer 61 of the control circuit 6 of the inverter 5.

Fig. 9 shows an operation flow according to this

embodiment. When the full pedal stroke/depression of the accelerator is excessive, namely, when the torque assist function is required (Step 440) immediately after the internal combustion engine has started, strong field control is performed. The driver signal is controlled and the current phase is adjusted so that the field current component decreases with a further rise of rotational speed (weak field control). At the same time, step-up chopper is also controlled (Step 440).

An induction motor can be adopted as a motor generator according to the present invention. Figs. 12 (a) and (b) show changes of the weak field current component by control of the motor torque and current phase of the stator winding in the motor operation mode, with respect to the rotational speed when the battery voltage is kept constant. Generally, when torque is required at a low rotational speed, control is performed so that the strong field current component is obtained. When rotational speed is high, current phase is controlled to get weak field current component in order to reduce counter electromotive force. When the field current component is positive in Fig. 7(b), the strong field control is performed. If it is negative, weak field control is performed.

The speed of the motor generator 8 (characteristic B) is 2000 rpm at the maximum torque, and the case where the

maximum rotational speed is 6000 rpm. The weak field rate of the motor generator B is 2000 to 6000, namely, 1 to 3. On the other hand, the rotational speed of the motor generator A (characteristic A) is 500 rpm at the maximum torque, and the maximum rotational speed is 6000 rpm. The weak field rate of the motor generator A is 500 to 6000, namely, 1 to 12.

When the motor generator is operated in the generator mode, generation operation is performed in the range from the idling rotational speed (about 700 rpm) of the internal combustion engine to the maximum rotational speed (6000 rpm). According to the method of adjusting where the current phase of the stator winding is adjusted in a high speed, the generation voltage is excessive, so there is a shortage in the amount of weak field current component. This makes it difficult to achieve agreement with the battery charging voltage. According to the method of the present invention, however, an induction motor having characteristic B can be used as a motor generator.

As described above, the present invention provides a motor generator and its control method in a battery-mounted hybrid car where the motor generator connected to the internal combustion engine is operated in the motor operation or generator mode over the range from low to high speed. In this hybrid car, stable power torque

characteristic and power generation characteristic can be ensured, and highly efficient control can be performed.

In other words, in a system where a motor generator for starting the internal combustion engine and for
5 generating power is connected directly between the internal combustion engine and transmission, and internal combustion engine is started and power is generated by the electric power of the battery through the inverter, a step-up chopper circuit is inserted between the main
10 (42-bolt) battery and inverter when the internal combustion engine has started, and d. c. voltage input of the inverter input is raised to a high voltage by the operation of the step-up chopper circuit and is applied in the motor operation mode of the motor generator,
15 according to the present invention. Compared with the conventional method of strong/weak field control alone based on current phase control of the stator winding in the prior art, the present invention expands the speed range permitting operations in both the motor and generator
20 modes, and ensures highly efficient and stable operation.

Further, the present invention offers the effect of setting a smaller value for the magnitude of weak field current control component in order to reduce the induced voltage in excess of battery charging voltage -- a problem
25 with the general permanent magnet type synchronous

generator (no output in weak field) --, thanks to the voltage step-up function and voltage step-down function.

Further, when the internal combustion engine is started, a high torque is required and the starting current is increased in the motor operation mode of the motor generator. However, the present invention allows the battery voltage to be increased, and a high voltage to be input to the inverter, with the result that high voltage can be applied to the motor. This ensures high voltage output and reduces starting current. This allows the current capacity of the switching element of the main circuit of the inverter to be reduced, with the result that a less expensive inverter can be provided.

This invention provides an excellent starting characteristic and high efficiency within the operation speed range of the internal combustion engine when any one of the permanent magnet type synchronous motor generator, jaw type magnetic pole synchronous motor generator and induction motor is used as a motor generator.

WHAT IS CLAIMED IS

1. A power generator in a hybrid car comprising:

5 a motor generator mechanically connected with the
crank shaft of an internal combustion engine for driving
a car wherein said internal combustion engine is started
by electric power supplied by a battery and power is
generated by rotation from said internal combustion engine
to charge a battery,

10 an inverter for controlling the drive and power
generation of a motor generator, and

a control circuit for controlling said inverter;
said hybrid car further characterized in that;

15 said motor generator is driven by battery power to
start said internal combustion engine, and, after said
internal combustion engine has started, said battery is
charged by the generator mode operation of said motor
generator using the power of said internal combustion
engine;

20 wherein a step-down chopper circuit is provided
between the battery and the inverter, and step-down control
is provided to ensure that the power generation voltage
will reach the level of the battery charging voltage
through a step-down chopper circuit.

2. A power generator in a hybrid car comprising:

a motor generator mechanically connected with the crank shaft of an internal combustion engine for driving a car wherein said internal combustion engine is started by electric power supplied by a battery and power is generated by rotation from said internal combustion engine to charge a battery,

an inverter for controlling the drive and power generation of a motor generator, and

a control circuit for controlling said inverter; said hybrid car further characterized in that;

said motor generator is driven by battery power to start said internal combustion engine, and, after said internal combustion engine has started, said battery is charged by the generator mode operation of said motor generator using the power of said internal combustion engine;

wherein a step-up chopper circuit is provided on the output side of the battery, and, when the motor generator is started by the electric power of the battery, the battery voltage is stepped up to drive said motor generator and to start said internal combustion engine.

3. A power generator in a hybrid car according to Claim 1 or 2 characterized in that said motor generator is a

permanent magnet field motor generator having its rotor equipped with a permanent magnet and constituting a field pole or a jaw type magnetic pole synchronous motor generator having its rotor with jaw type magnetic pole field, wherein the weak field rate is 1 to less than 4 .

4. A power generator in a hybrid car according to Claim 1 or 2 characterized in that said motor generator is an induction motor generator having its rotor equipped with multiple secondary conductors and the weak field rate is 1 to 3 or more.

5. A power generator in a hybrid car according to any one of Claims 1 to 4 characterized in that

said battery comprises an auxiliary battery of 14-volt charging voltage as a light source for a lamp or the like, and a main battery of 42-volt charging voltage;

said internal combustion engine is started by the electric power supplied from said main battery through said motor generator;

power is generated by said motor generator through rotation from said internal combustion engine, thereby charging the main battery; and

the battery is charged by operation of said motor generator in the generation mode using the power of the

internal combustion engine after said internal combustion engine has started;

5 wherein, if the voltage generated by said motor generator is greater than charging voltage of said main battery, voltage control is performed by said step-down chopper circuit to step down said voltage until it agrees with the charging voltage of said main battery.

10 6. A motor generator control method for a hybrid car comprising:

15 a motor generator mechanically connected with the crank shaft of an internal combustion engine for driving a car wherein said internal combustion engine is started by electric power supplied by a battery and power is generated by rotation from said internal combustion engine to charge a battery,

 an inverter for controlling the drive and power generation of a motor generator, and

20 a control circuit for controlling said inverter; said hybrid car further characterized in that;

 if the voltage generated by said motor generator is greater than charging voltage of said main battery, voltage step-down control is performed by a step-down chopper circuit to step down said voltage until it agrees with the charging voltage of said main battery.

25

7. A motor generator control method for a hybrid car according to Claim 6 characterized in that said battery is charged by operation of said motor generator in the generation mode wherein;

5 if the voltage generated by said motor generator is greater than charging voltage of said main battery, said voltage is stepped down by said step-down chopper circuit; at the same time, and the current phase of the stator winding of said motor generator is controlled to get weak field
10 component by armature reaction magnetic flux to ensure that said generated voltage agrees with said battery charging voltage.

8. A motor generator control method for a hybrid car
15 comprising:

a motor generator mechanically connected with the crank shaft of an internal combustion engine for driving a car

wherein said internal combustion engine is started by
20 electric power supplied by a battery and power is generated by rotation from said internal combustion engine to charge a battery,

an inverter for controlling the drive and power generation of a motor generator, and

25 a control circuit for controlling said inverter;

said hybrid car further characterized in that;

when said motor generator is started by electric power of said battery, a step-up chopper circuit is provided on the output side of said battery to step up said battery
5 voltage to drive said motor generator and start said internal combustion engine, and;

if the voltage generated by said motor generator is greater than charging voltage of said main battery, voltage step-down control is performed by a step-down chopper
10 circuit to step down said voltage until it agrees with the charging voltage of said main battery.

9. A motor generator control method for a hybrid car according to Claim 8 characterized in that, in the startup
15 operation by said motor generator, the current phase of a stator winding is controlled by an inverter to get strong field current component whereby said internal combustion engine is started.

20 10. A motor generator control method for a hybrid car according to Claim 8 characterized in that;

said motor generator is a permanent magnet synchronous motor generator or jaw type magnetic pole synchronous motor generator;

25 when said internal combustion engine is started,

strong field control is made by the inverter until the rotational speed requiring the maximum torque is reached, and, at the same time, the step-up chopper circuit is operated to make motor-applied voltage greater than the battery voltage and to get the motor current to have a specified current value, thereby obtaining the maximum torque; and

when torque assist function is used until a high rotational speed is reached, weak field current component control is performed through control of the current phase of said stator winding, and, at the same time, the step-up chopper circuit is operated to increase the motor applied voltage so that the motor current is kept at the minimum.

11. A motor generator control method for a hybrid car according to Claim 6 characterized in that;

said motor generator is a permanent magnet synchronous motor generator or jaw type magnetic pole synchronous motor generator;

when power is generated by said motor generator after start of said internal combustion engine is started, stator winding current phase is controlled to get strong field current component if the internal combustion engine speed is close to idling speed;

then with the increase in internal combustion engine

speed, the current phase of said stator winding is controlled to get strong field current component, thereby keeping generation voltage at the level of charging voltage; and

5 with further increase in engine speed, generation voltage is stepped down by the step-down chopper circuit with the state of weak field current component kept unchanged, and voltage control is made to ensure that generation voltage agrees with battery charging voltage.

10

12. A motor generator control method for a hybrid car according to Claim 8 characterized in that;

 said motor generator is an induction motor generator;

 when said internal combustion engine is started, the

15 current phase of said stator winding is controlled so that strong field control component is obtained until the rotational speed requiring the maximum torque is reached, and at the same time, the step-up chopper circuit is operated to make motor-applied voltage greater than the
20 battery voltage, thereby obtaining the maximum torque even if the stator winding current is small at the time of internal combustion engine startup; and

 when torque assist function is used until a high rotational speed is reached, weak field control is
25 performed, and, at the same time, the step-up chopper

circuit is operated to increase the motor-applied voltage, thereby obtaining the assist torque.

13. A motor generator control method for a hybrid car according to Claim 8 characterized in that;

when said motor generator is started by said battery power, a step-up chopper circuit is installed on the output side of said battery and the conversion voltage ratio of said battery voltage is set at 1.5 times or more, to ensure that the current capacity of the switching element of said inverter main circuit is smaller than that of the switching element of said step-up chopper circuit.

14. A motor generator control method for a hybrid car according to any one of Claims 6 to 13 characterized in that

said battery comprises a auxiliary battery of 14-volt charging voltage as a light source for a lamp or the like, and a main battery of 42-volt charging voltage;

said internal combustion engine is started by the electric power supplied from said main battery through said motor generator;

power is generated by said motor generator through rotation from said internal combustion engine, thereby charging the main battery; and

the battery is charged by operation of said motor generator in the generation mode using the power of the internal combustion engine after said internal combustion engine has started;

- 5 wherein, if the generation voltage of said motor generator is greater than the charging voltage of said main battery, voltage control is performed to step down the generation voltage through said step-down chopper circuit so that it agrees with the charging voltage of said main
- 10 battery is reached.

FIG. 1

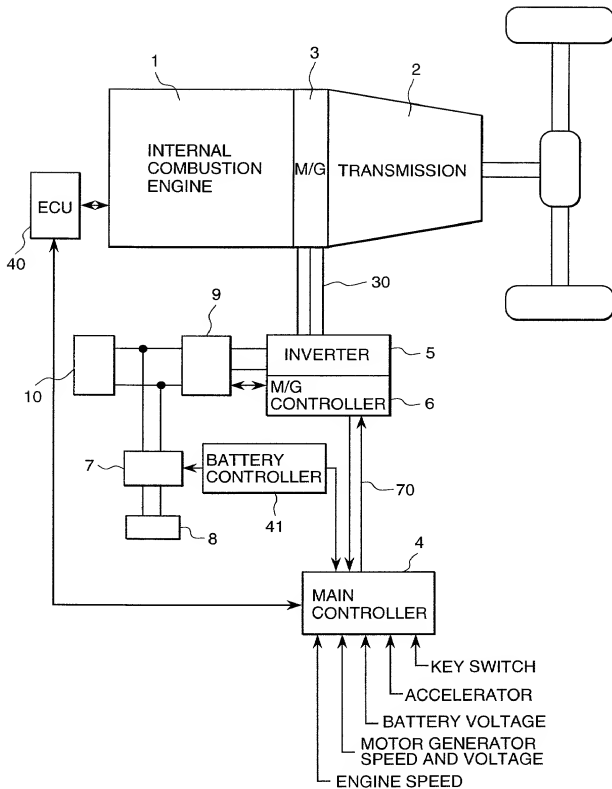


FIG. 3

OPERATION MODE	START OF INTERNAL COMBUSTION ENGINE	TORQUE ASSIST FOR INTERNAL COMBUSTION ENGINE	POWER GENERATION
CONTROL	(STEP-UP CHOPPER)+ STRONG MAGNETIC FIELD	(STEP-UP CHOPPER)+ STRONG MAGNETIC FIELD WEAK MAGNETIC FIELD	STEP-DOWN CHOPPER+ WEAK MAGNETIC FIELD

FIG. 5

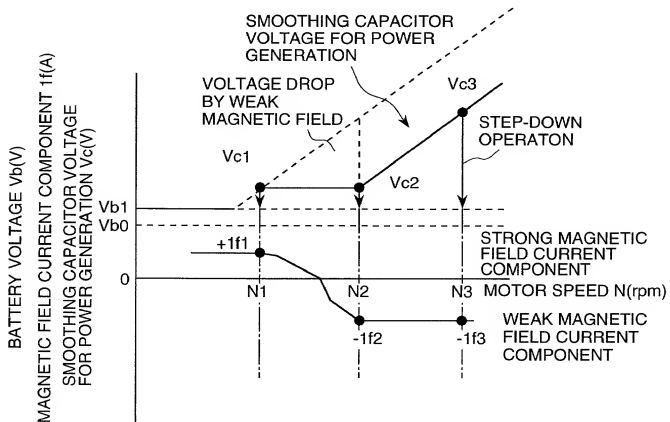
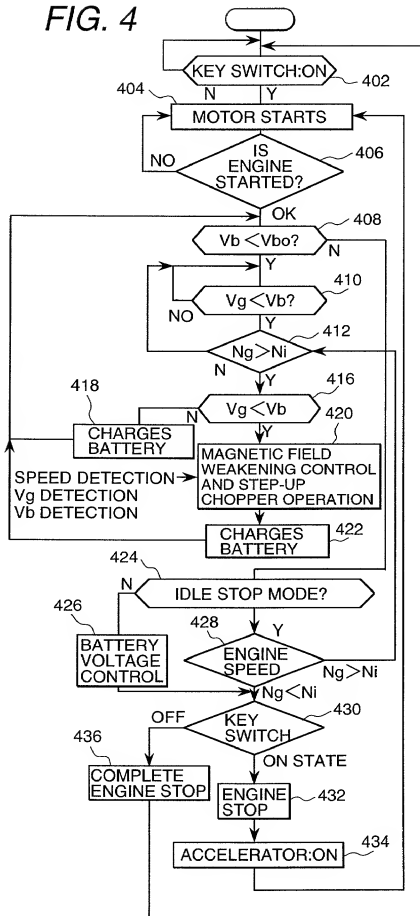


FIG. 4



ENGINE SPEED(N_g)
 IDLING SPEED(N_i)
 V_g :POWER GENERATION
 VOLTAGE
 V_b :BATTERY CHARGING
 VOLTAGE

09/936481

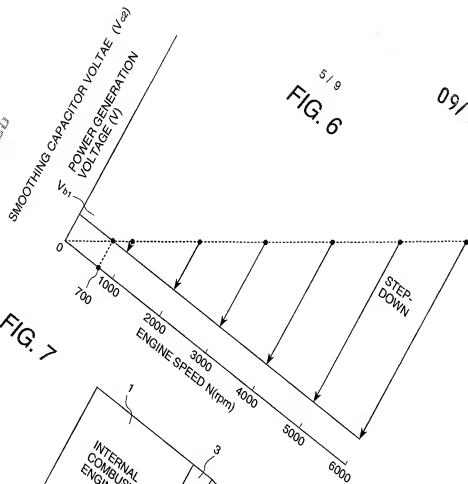


FIG. 7

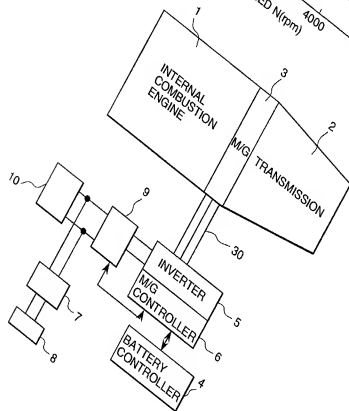


FIG. 8

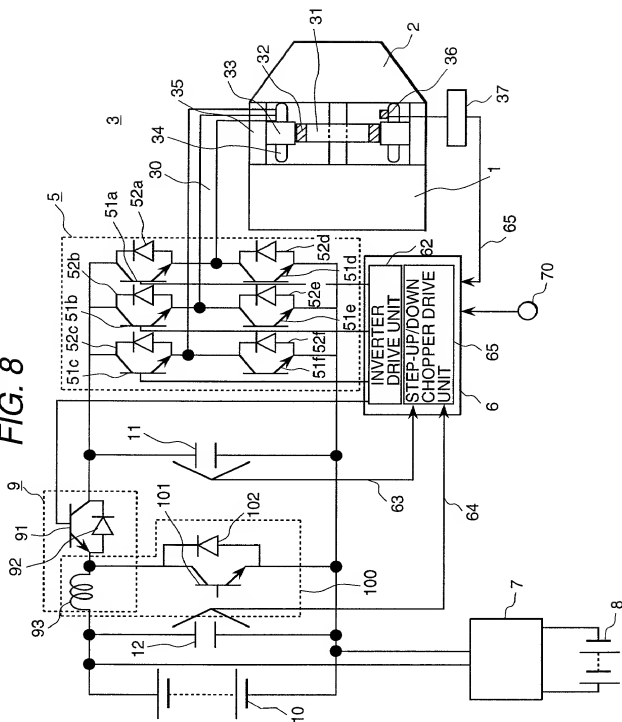


FIG. 9

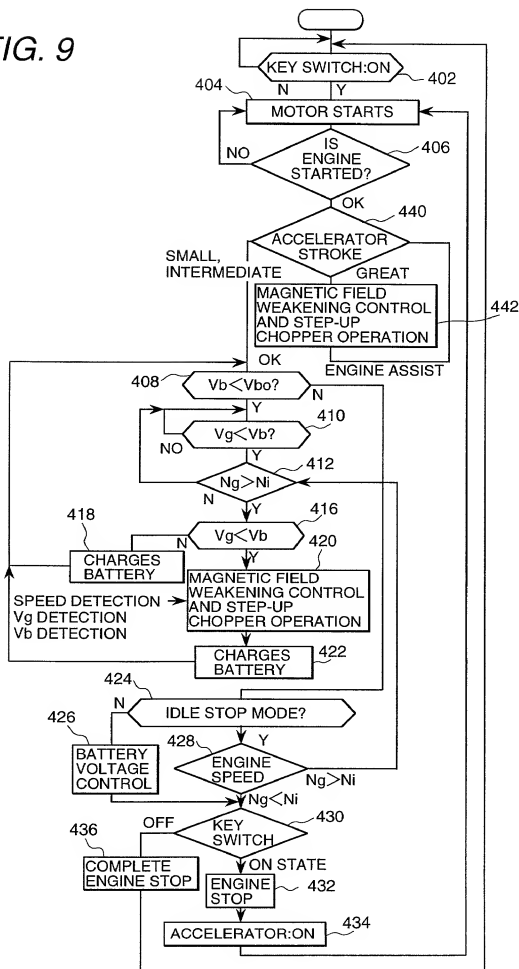


FIG. 10

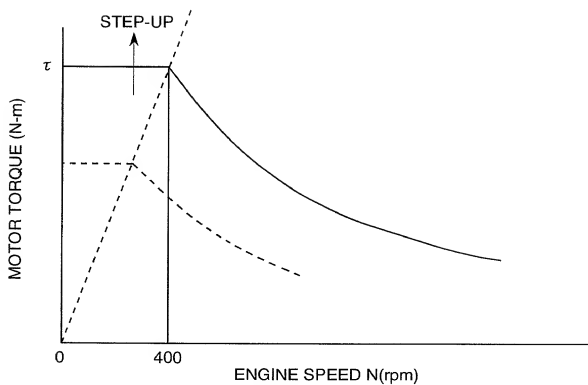


FIG. 11

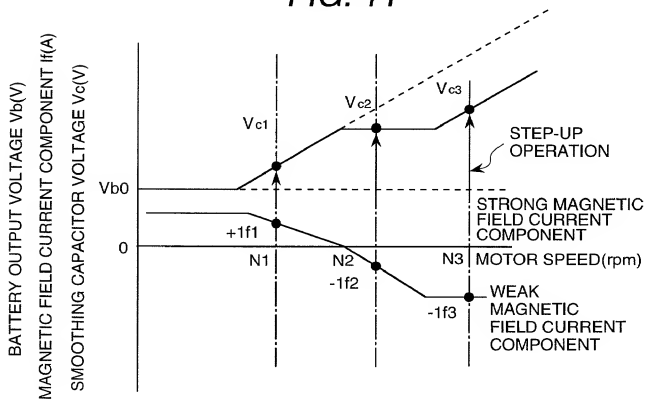


FIG. 12(a)

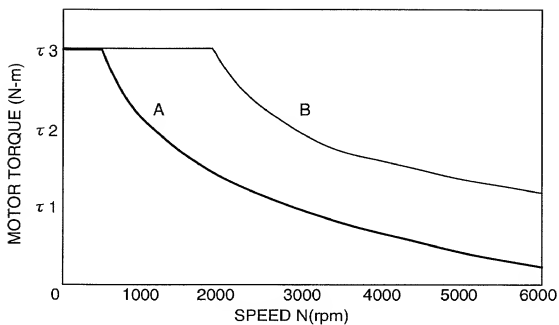
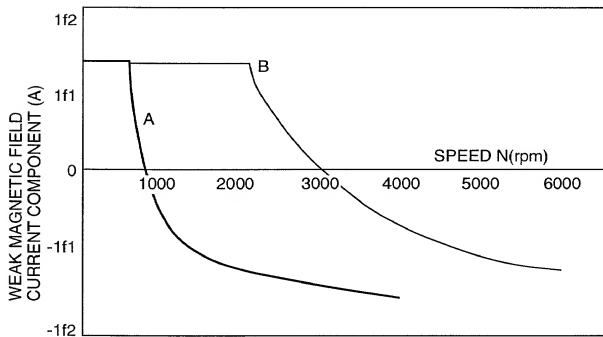


FIG. 12(b)



#3

Declaration and Power of Attorney For Patent Application

特許出願宣言書及び委任状

Japanese Language Declaration

日本語宣言書

下記の氏名の発明者として、私は以下の通り宣言します。

As a below named inventor, I hereby declare that:

私の住所、私書箱、国籍は下記の私の氏名の後に記載された通りです。

My residence, post office address and citizenship are as stated next to my name.

下記の名称の発明に関して請求範囲に記載され、特許出願している発明内容について、私が最初かつ唯一の発明者（下記の氏名が一つの場合）もしくは最初かつ共同発明者であると（下記の名称が複数の場合）信じています。

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

MOTOR GENERATOR IN HYBRID CAR AND CONTROL

METHOD THEREOF

上記発明の明細書（下記の欄で×印がついていない場合は、本書に添付）は、

The specification of which is attached hereto unless the following box is checked:

☐ 月 日に提出され、米国出願番号または特許協定条約国際出願番号を _____ とし、
(該当する場合) _____ に訂正されました。

☒ was filed on September 20, 1999
as United States Application Number or
PCT International Application Number
PCT/JP99/05115 and was amended on _____
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私は、特許請求範囲を含む上記訂正後の明細書を検討し、内容を理解していることをここに表明します。

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

私は、連邦規則法典第37編第1条56項に定義されるとおり、特許資格の有無について重要な情報を開示する義務があることを認めます。

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

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私は、米国法典第35編119条(a)-(d)項又は365条(b)項に基づき下記の、米国以外の国の少なくとも一カ国を指定している特許協力条約365(a)項に基づく国際出願、又は外国での特許出願もしくは発明者証の出願についての外国優先権をここに主張するとともに、優先権を主張している、本出願の前に出願された特許または発明者証の外国出願を以下に、枠内をマークすることで、示している。

Prior Foreign Application(s)

外国での先行出願

(Number) (番号)	(Country) (国名)
(Number) (番号)	(Country) (国名)

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(Application No.) (出願番号)	(Filing Date) (出願日)
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Priority Not Claimed

優先権主張なし



(Day/Month/Year Filed) (出願年月日)

(Day/Month/Year Filed) (出願年月日)

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(Application No.) (出願番号)	(Filing Date) (出願日)
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(Status: Patented, Pending, Abandoned) (現況: 特許許可済、係属中、放棄済)
(Status: Patented, Pending, Abandoned) (現況: 特許許可済、係属中、放棄済)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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として、下記の者を指名いたします。(弁護士、または代理人
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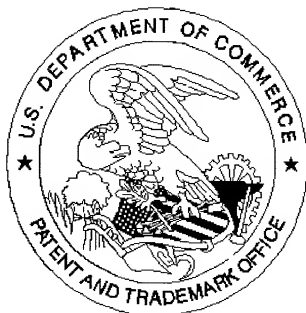
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住所		Residence Hitachiota, Japan JPX
国籍		Citizenship Japan
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第九共同発明者の署名	日付	Ninth inventor's signature Date
住所		Residence
国籍		Citizenship
私書箱		Post Office Address

(第十以降の共同発明者についても同様に記載し、
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